# PERFGRINE™ Takes Aim at Cancer Tumors

Members of the PEREGRINE team are (left to right) Brian Guidry, Don Jong, Rosemary Walling, Ed Moses, Tom Daly, Sarita May, Paul Bergstrom, Ralph Patterson, Don Fujino, Ron House, Christine Hartmann Siantar, Jim Rathkopf, Clark Powell, and Dave Knapp. Not pictured are Larry Cox, Lila Chase, Dewey Garrett, Steve Hornstein, Bill Chandler, and Alexis Schach von Wittenau.

A revolutionary new tool for analyzing and planning radiation treatment for cancer patients will be appearing in hospitals within the next few years. Using their storehouse of knowledge and data on nuclear science and radiation transport, Lawrence Livermore scientists have developed PEREGRINE, a hardware and software system that addresses the problem of radiation therapy dosage using fundamental physics principles.

Each year, about 100,000 Americans die from cancerous tumors that doctors thought were curable. Using current methods for analyzing radiation, doctors unknowingly leave areas of the tumors untreated. Livermore researchers hope that PEREGRINE will improve the efficacy of radiation therapy by helping doctors to direct the radiation accurately. According to Ralph Patterson, who is leading the project, "The PEREGRINE dose calculation system is the best tool available for accurately predicting radiation dose to tumors."

Members of the PEREGRINE team hold one patent related to PEREGRINE and have filed three others. Livermore has recently selected the NOMOS Corporation as a partner to transfer this unique system from the Laboratory into medical clinics. (See also *S&TR*, May 1997, "PEREGRINE: Improving Radiation Treatment for Cancer," pp. 4–11.)

### How It Works

PEREGRINE relies on the Monte Carlo mathematical technique to predict the dose delivered to cancer patients receiving photon beam therapy, the most common form of radiation therapy. During treatment, a patient receives trillions of photons. The Monte Carlo method reconstructs the treatment by selecting a random sample of photon particles and tracking them through a computer model of the radiation delivery device and a model of the tumorous region, based on a computed tomography (CT) scan of the patient. Everything that happens to the photons after they leave the x-ray machine—colliding with an electron in the skin, ionizing a hydrogen atom in the blood, perhaps being absorbed by calcium in the bone—is calculated in the model. The fundamental laws of physics and Livermore's world-renowned collection of nuclear and radiation data serve as the basis for the model.

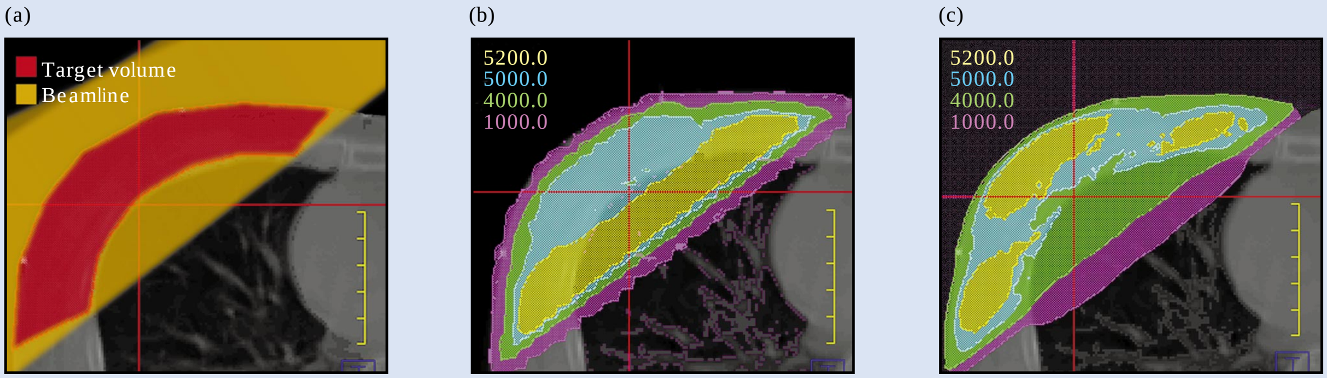
By recording the dose (radiation energy absorbed per unit mass of tissue) deposited by each of the millions of sample particles tracked, the system develops a detailed map of the radiation dose that will be deposited in the patient. This information is graphically displayed, giving doctors the ability to plan treatments that direct maximum radiation dose to the tumor while minimizing damage to nearby healthy tissue.

Scientists have known since the 1950s that the Monte Carlo technique is the best way to accurately calculate radiation dose. The problem has been that these calculations took days or even weeks on computers. As recently as 1995, a full Monte Carlo analysis for a single patient took about 200 hours. But recent advances in parallel computing using small desktop computers allow many processors to operate simultaneously and complete a Monte Carlo radiation analysis in just 10 minutes.

PEREGRINE uses commercial computer boards that support multiple processing and are interconnected with an internal high-speed network. A flexible hardware design allows the system to be configured as needed and upgraded as requirements and computing technology change. The use of hardware commonly found in desktop computers makes the PEREGRINE systems affordable.

### Why PEREGRINE Matters

Predictions of radiation dose differ by as much as 30 percent between conventional radiation planning techniques and the Monte Carlo method. Conventional techniques may result in the tumor receiving up to 30 percent more or less radiation than the physician intended. At the same time, healthy tissue may be




This breast cancer case highlights the importance of accurate dose calculations for correct dose coverage of the tumor and sensitive surrounding lung tissue. (a) The radiation applied to the target is shown in general. (b) While conventional dose calculations show that the prescribed dose level covers the entire tumor, (c) PEREGRINE calculations suggest that for this treatment, the prescribed dose shows a higher skin dose, deeper penetration of dose into the lung, and a different dose distribution within the chest wall.

receiving too much. A comparison of conventional and Monte Carlo prediction methods for a case of breast cancer is shown in the figure above.

The Monte Carlo technique is much more effective than conventional methods because it considers the varying densities in the patient's body—of bone, soft tissue, air passages, and so on. This contrasts with current dose calculation methods that model the body as a virtually homogeneous "bucket of water." Even with a CT scan that provides a three-dimensional electron-density map of the body, inhomogeneities such as bone and airways are ignored or highly simplified. Radiation treatments are calculated using interpolated data from dose measurements made in water. The calculations are also based on various simplifications of the way radiation is produced by the source, how radiation travels through the body, and how much energy is deposited.

Some tumors are particularly difficult to treat with radiation because of their proximity to vital organs, the abundance of different tissue types in the area, and the differences in their susceptibility to radiation. Cancers of the head, neck, lungs, and reproductive organs are examples. Too small a dose to the tumor can result in recurrence of the cancer, while too large a dose to healthy tissue can cause complications or even death. Because of the inaccurate dose provided by today's calculations, doctors trying to avoid damage to healthy tissue sometimes undertreat cancerous tissue.

PEREGRINE meets all of these clinical challenges. It can more exactly model the radiation beam delivery system being used for each treatment, accurately model the buildup of dose at the skin surface, and explicitly account for inhomogeneities in the body such as air, muscle, bone, and lung that are identified on the patient's CT scan.

## Beyond Photons

About 90 percent of radiation treatment patients receive photon therapy, which is PEREGRINE's principal application. PEREGRINE may also be applied to the less frequently used electron-beam therapy and to brachytherapy, which is radiation therapy from an internally planted radiation source. It is effective for radiography, which predicts the pattern of radiation that is transmitted through a patient or other object. It also promises to advance radiation oncology research into heavy-particle therapy and radioimmunotherapy, which uses the chemistry of the body's immune system to target radioactive compounds at metastasized cancerous tumors.

Widespread use of PEREGRINE dose calculations has the potential to foster more accurate clinical trials and therefore more reliable implementation of clinical trial results. It will also provide accurate estimates of doses required for tumor control and normal tissue tolerance.

Improving the effectiveness of radiation therapy will have immediate, positive results for the hundreds of thousands of people who are diagnosed with cancer every year. With PEREGRINE, the usefulness of radiation therapy may also be broadened, offering a less invasive, less expensive alternative to surgery.

*—Katie Walter*

**Key Words:** cancer treatment, Monte Carlo calculations, PEREGRINE, radiation dose, radiation treatment planning.

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